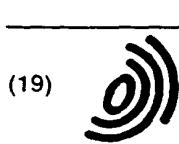


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### (54) Process of plugging cooling holes of a gas turbine component

(57) Process of plugging cooling holes (4) of a gas turbine component (1) with an external surface (7), comprising a cavity (2) and a plurality of cooling holes (4) before coating the gas turbine component (4), characterised in that mask material (6) is applied to the external surface (7) of the component (1) while a fluid is forced through the cooling holes (4), the mask material (6) is

thickened while the fluid is forced through the cooling holes (4), the cooling holes (4) are plugged with plug material (6b), the mask material (6a) is removed from the external surface (7) of the component (1), the component (1) and the plugged cooling holes (4) are coated and the plug material (6b) is removed from the cooling holes (4).

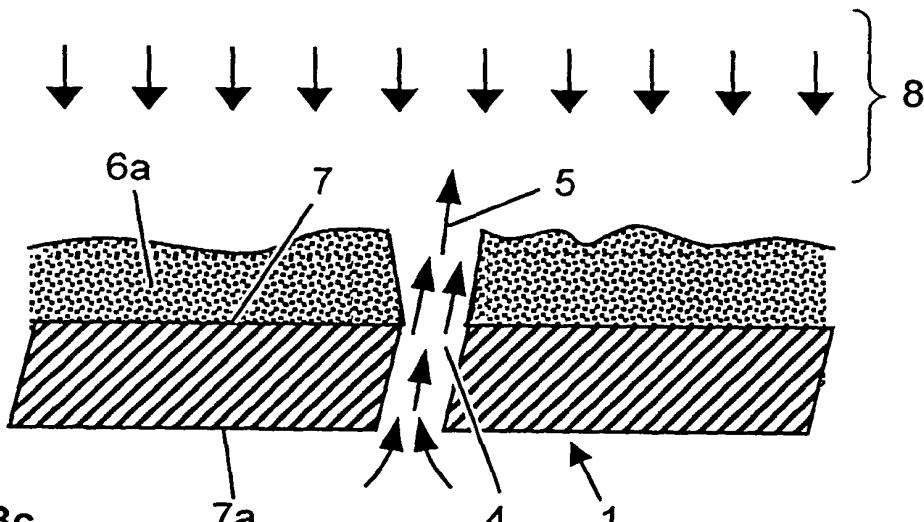


Fig. 3c

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**Description****FIELD OF INVENTION**

**[0001]** The invention relates to a process of plugging cooling holes of a gas turbine component.

**STATE OF THE ART**

**[0002]** Components such as gas turbine blades, vanes and other cooled parts often contain cavities that distribute cooling air to a plurality of holes in the wall of the part which lead to the outer surface. Most turbine components are coated for protection from oxidation and/or corrosion with, for example, an MCrAlY coating (base coat) and some are also coated with a thermal barrier coating (TBC) for thermal insulation. The demands of operation of the parts in a gas turbine often lead to the degradation of the coating before the structural integrity of the underlying part itself is degraded. Hence, the base coat and TBC must be removed and re-applied.

**[0003]** The re-application of the coatings can be very problematic for parts with a large number of cooling holes. Often the base coat can reach thicknesses of 150-300 µm, and the TBC may be another 200 - 500 µm in thickness. The combined thicknesses of these coatings would have a very significant (and negative) influence on the effectiveness of the cooling holes if the coatings were deposited into these holes, especially considering that some holes are 1 mm or less in diameter. Specially shaped cooling holes are particularly susceptible to this as their effectiveness depends heavily on the accuracy of the shape of the hole.

**[0004]** There have been several disclosures relating to this problem and there are several widely known practices. Those skilled in the art are aware that a common practice is to braze or weld the holes closed with a suitable material after the old coatings have been removed, re-apply the new coatings, and re-manufacture the holes. The problem with this is that the brazing or welding operations introduce zones of weakness into the material. Normal hole manufacturing operations have errors associated with the placement of the holes, and when residual welding or brazing material is left, the zones of weakness go into operation with the part and compromise the mechanical integrity of the part.

**[0005]** One disclosure which offers a solution to this is US 5,702,288, in which an abrasive slurry is injected into the cavity of the component and forced through the cooling holes which were partially covered by the coating material. There was no welding or brazing closed prior to coating. However this also abrades the internal cooling configuration (ribs), any inserts, and also the non-coated portion of the cooling holes.

**[0006]** Another disclosure which offers a better solution is US 4,743,462, in which fugitive plugs are inserted into the cooling holes and partially volatilize during the

coating process. The volatilization disrupts the coating in the region of the hole, and once the plugs are completely removed the holes are essentially free of coating and the cooling air will be unimpeded. The disadvantage of this method is that the large portion of the plug which blocks the surface does not constitute an even continuation of the cooling hole (it is specified to be larger than the cooling hole opening), therefore the path of the cooling air will be different from the intention of the design.

**5** **[0007]** This is particularly true for film cooling holes and specially shaped holes which are highly dependent on the shape of the hole near the external surface of the part. If the walls of the cooling holes are not maintained straight all the way through the coating layers (again, MCrAlY and TBC may amount to 0.8 mm or more in thickness) the cooling efficiency will be significantly compromised.

**10** **[0008]** A further disadvantage of the method disclosed in US 4,743,462 is that the plugs must all be placed individually into the cooling holes. For small simple aero-engine parts such as the one illustrated in the disclosure (containing only several rows of cooling holes at the leading edge) this is feasible, however for large turbine components of land-based gas turbines which may contain several hundred cooling holes, it is no longer feasible to individually place plugs into each hole. This is further complicated by the fact that each component may be manufactured with several different types of cooling holes - including conical, straight cylindrical and holes with changing wall angles. Each type of cooling hole would require its own specially designed plug.

**15** **[0009]** **[0008]** A further disclosure in which all holes are plugged at once is given in US 5,800,695. A masking agent is placed into the cooling configuration and forced through until it fills the cooling holes from the inside, but only up to the level of the exterior surface of the component. A coating is then applied, in this case electrolytically applied platinum. Due to the non-conductivity of the plastic maskant cited in the disclosure, no Pt would be deposited on the masking agent in the cooling holes. However, if the coating were deposited using thermal spraying techniques, it would coat over the maskant in the cooling holes, forming a layer that would remain after maskant removal. This layer would have to be removed.

**20** **[0009]** No solution is offered for this problem - in particular, how to remove the layer of coating material in such a way that the intended cooling hole design is maintained through the thickness of the coating material.

**25** **[0009]** In addition, only plastic materials are specified as maskant materials, and in US 4,743,462 the mask material is specified to volatilize at a temperature below that of the deposition process. The problem with this is that part requiring a MCrAlY coating and TBC must have the MCrAlY coating "diffusion bonded" by a high temperature heat treatment (about 1000°C - 1150°C in vacuum) before the TBC can be applied. These specified materials would not be retained for the TBC coating process, and would either have to be re-applied, or the

advantage of the masking would be lost. Indeed, in patent US 5,800,695 the example process clearly states that after electrolytic platinum coating, the maskant is removed and then the parts are aluminized, with no mention of protecting the cooling holes from Al deposition.

#### SUMMARY OF THE INVENTION

**[0010]** It is object of the present invention to find a process of plugging all cooling holes of component at once, with the mask defining the walls of the cooling holes beyond the external surface of the component so that the deposited coating material forms the intended shape of the cooling hole.

**[0011]** According to the invention a process was found for plugging cooling holes of a gas turbine component with an external surface, comprising a cavity and a plurality of cooling holes before coating the gas turbine component, characterised in that mask material is applied to the external surface of the component while a fluid is forced through the cooling holes, the mask material is thickened while the fluid is forced through the cooling holes, the cooling holes are plugged with plug material, the mask material is removed from the external surface of the component, the component and the plugged cooling holes are coated and the plug material is removed from the cooling holes.

**[0012]** The most important improvement of the present invention over the prior art is that the cooling holes are re-formed during the coating deposition processes to their originally intended design, even through the thickness of the applied coating. This can be further improved by forcing a fluid containing abrasive particles through the cooling holes, after the exposing of the masking of the external surface to the energy source and before plugging the cooling holes.

**[0013]** Many different energy sources, different mask materials and plug materials may be used for the process of the invention. The plug material may with advantage contain particles of solid material so that after thickening and with the proper heat treatment to volatilize part of the plug material, a porous solid form is left which can withstand the high temperatures of the diffusion heat treatment necessary for the bonding between base material of the component and the MCRAIY coating, before applying the thermal barrier coating TBC.

**[0014]** Another advantages is achieved when an insert is placed into the cavity of the component to avoid liquid mask material entering into the cavity and thickening there.

#### SHORT DESCRIPTION OF THE DRAWINGS

**[0015]** It is shown by

**Fig. 1** gas turbin blade with cooling configuration,  
**Fig. 2** section by line II - II through the gas turbine

- 5 **Fig. 3a** blade shown in figure 1, comprising a cavity and a plurality of cooling holes,  
**Fig. 3b** first step of the process according to the invention, blowing a fluid through the cooling holes, shown as an example at one cooling hole as given in circle III in figure 2,  
**Fig. 3c** second step of the process according to the invention, depositing a mask material on the external surface of the component while blowing the fluid through the cooling hole,  
**Fig. 3d** third step of the process according to the invention, thickening the mask material by means of energy while still blowing the fluid through the cooling hole,  
**Fig. 3e** 10 an optional step of the process according to the invention, forcing a fluid containing an abrasive slurry through the cooling hole and thereby getting well shaped holes,  
**Fig. 3f** 15 fourth step of the process according to the invention, masking the cooling hole with a plug material,  
**Fig. 3g** 20 fifth step of the process according to the invention, the component after the removing of the thickened mask material from the external surface of the component while the plug material rests within the cooling hole extending beyond the external surface of the component,  
**Fig. 3h** 25 sixth step of the process according to the invention, deposition of the coating material on the external surface of the component,  
**Fig. 4** 30 seventh step of the process according to the invention, removing the plug material from the cooling hole and  
35 a cross section through a gas turbine blade with an insert within the cavity.

40 **[0016]** The drawings show only the parts important for the invention. Same elements will be numbered in the same ways in different drawings.

#### PREFERRED EMBODIMENT OF THE INVENTION

45 **[0017]** Figure 1 shows a component 1 such as a blade or vane of a gas turbine engines comprising a cavity 2, not visible in figure 1, a platform 3 and cooling holes 4, which are on the external surface 7 of the component 1 as well as on the platform 3 of the component 1. The present invention relates to a process of masking cooling holes 4 in the component 1 before the deposition of coating material on the external surface 7 of the component 1 takes place.

50 **[0018]** According to line II- II in the figure 1 figure 2 shows a cross section through the component 1. The component 1 comprising a cavity 2 and the cooling holes 4. The number of the cooling holes 4 is given only as an example and may vary on the purpose the component 1 is used for. The component 1 has an external

surface 7 and an internal surface 7a.

[0019] It is possible to apply the process for the coating of a new component 1 as well as to a component 1 which has to be repaired after use. In that case an already coated component 1 will by any means (chemical stripping with HCl, waterjet, high speed machining, etc.) be stripped of the old coating to reveal the external surface 7 of the component 1. The external surface 7 of the component 1 and surfaces of the cooling holes 4 may be cleaned or otherwise prepared to receive the mask material.

[0020] The steps of the process of the invention are given in figures 3a to 3h, which show a cooling hole 4 from the component 1 in detail as given as an example in the circle III in the figure 2.

[0021] The figure 3a shows the first step of the process according to the invention. A flow 5 of a fluid such as air or water will be forced through the cooling hole 4. As seen in figure 3b the external surface 7 of the component 1 at the same time as the flow 5 is forced through the cooling holes 4 is masked with the mask material 6. The component 1 will be coated with, sprayed with, or immersed in a mask material 6 which is at least partially liquid and which thickens, which means to become more viscous or solid when exposed to an energy source. The flow 5 impedes any mask material 6 from entering the cooling hole 4 and also defines the shape of the cooling hole 4 that the mask material 6 takes as it thickens on the external surface 7 of the component 1. This method causes the mask material 6 to define the shape of the cooling hole 4 above the external surface 7 to a shape very close to that originally intended.

[0022] This operation may be repeated several times until a desired thickness of the mask material 6 is achieved: the preferred range is at least of the coating(s) to be applied, the most preferred range is at least two to three times the thickness of the coating(s) to be applied.

[0023] As mask material 6 different substances may be used:

1. an organic material or
2. a resin of a plastic, such as polyurethane, a polyurethane oligomer mixture, poly(isobutyl methacrylate), poly(vinyl toluene), polypropylene or a polypropylene / polyurethane oligomer mixture, the class of vetcenes or silicones, or any photo-polymerizing resin or mix of resins,
3. the mask material 6 may also be a substance that is not at least partially liquid but rather a powder, which means a collection of solid particles. Thickening of the powder then refers to the agglomeration and the sticking together to form clumps or a large solid mass of individual powder particles. The powder would have to be sensitive to an energy source, which means that the powder particles agglomerate under the influence of the energy source or

4. a wax or a hydrocarbon, which is solid at room temperature.

[0024] Figures 3c shows the third step of the process according to the invention. The desired energy source will be placed on the side of the external surface 7 so that the energy 8 impinges directly on said mask material 6 which thickens by that means. In the figure 3c the thickened mask material 6a is shown with different pattern. The mask material may also thicken without the use of an energy source (e.g. the wax which is solid at room temperature). In this case the freshly masked component need only be placed in an environment (or use a fluid) of such a temperature that the mask thickens as it changes temperature.

[0025] Different energy sources may be used in order to obtain the desirable result:

1. it can be electromagnetic such as visible light, ultraviolet light or infrared light,
2. it can be a device providing collimated light such as a laser,
3. the energy source can also be a device providing light of a single wavelength or a distribution of wavelengths centred around a desired wavelength with a narrow distribution band,
4. the energy source can be an infrared radiation or
5. the energy source can be sonic vibrations ranging from infrasonic (below 20 Hz) to ultrasonic (above 20,000 Hz) frequencies. In this case the energy source can be a transducer (i.e. an ultrasonic transducer) or
6. the energy is microwave radiation.

[0026] One variation of this invention after the desired thickness of the thickened mask material 6a is achieved, a fluid 5a containing abrasive particles is forced through the cooling holes 4. This is shown in figure 3d. The abrasive particles will be hard enough to wear away the thickened mask material 6a but not the metallic part of the component 1 itself. This is to achieve more accurately (when this effect is needed) the originally intended shape of the cooling hole 4 through the coating(s) beyond the external surface 7 of the component 1.

[0027] Figures 3e shows the fourth step of the process according to the invention. Once the desired thickness of the thickened mask material 6a is achieved, the cooling hole 4 and the hole above the external surface 7 of the component 1 are filled with a plug material 6b which is sufficiently different from the thickened mask material 6a. After plugging the cooling holes 4 the thickened mask material 6a is removed while leaving the plug material 6b essentially in place. This is shown in figure 3e. As an example the plug material 6b could be a version of the mask material 6a containing a high density of metallic or ceramic particles.

[0028] In general speaking the plug material 6b could be

1. an organic material
2. a resin of a plastic, such as polyurethane, a polyurethane oligomer mixture, poly(isobutyl methacrylate), poly(vinyl toluene), polypropylene or a polypropylene / polyurethane oligomer mixture, the class of vetones or silicones, or any photo-polymerizing resin or mix of resins. in a variation of that it could contain particles of metal or oxide metals such as silica, magnesia, calcia, alumina, zirconia, yttria or mixture thereof, in an embodiment as described above the thickened plug material 6b containing the metal or oxide particles is heated so as to volatilise or otherwise remove the organic portion of the plug material before the coating(s) are deposited on the component 1 surface, it also may contain binding agents which are effective in holding together the solid particles of the metal or oxide particles after the organic portion of the plug material 6b is removed,
3. the plug material 6b may also be a substance that is not at least partially liquid but rather a powder, which means a collection of solid particles. Thickening of the powder then refers to the agglomeration and the sticking together to form clumps or a large solid mass of individual powder particles. The powder would have to be sensitive to an energy source, which means that the powder particles agglomerate under the influence of the energy source. The powder could be mixed with particles of metal or oxide material such as silica, magnesia, calcia, alumina, zirconia, yttria or mixture thereof
4. the plug material 6b is a ceramic slurry or paste with essentially no polymerizing agent included.

[0029] Once the plug material 6b is hardened the entire assembly could be heated to a temperature that would remove the mask material 6a and partially sinter the ceramic or metallic particles in the plug material 6b. The plug material 6b will extend into the cooling hole 4 of the component 1 so that the plugs will remain in place after the thickened mask material 6a is removed. This is shown in the figure 3g. After the mask material 6a is removed, the component 1 external surface 7 may be specially cleaned in preparation of the coating deposition. As seen in figure 3f the depositing of the coating 9 on the external surface 7 will take place directly on the masked cooling holes 4 with the means known in the state of the art. There may be more than one coating 9 depositions such as MCrAlY and TBC.

[0030] After the coating process(es) are completed, the plug material 6b will be removed to reveal cooling holes 4 essentially free of coating material 9 and with walls that run consistently through the newly deposited coating material 9. This is shown in figure 3h. This may be done by heating the components in a vacuum furnace at 600°C for 2 hours. Residual ceramic may be removed by selective chemical cleaning, for example using KOH.

[0031] It might be an advantage to place an insert 10 to the internal surface 7a within the cavity 2 of the component 1 as shown in figure 4. The insert 10 is placed in the cavity 2 in order to avoid excess and unwanted plug material 6b from thickening in the cavity 2. The insert 10 may have a special coating which allows the easy withdrawal from the component cavity 2 once the plug material 6b has been thickened.

[0032] It is possible that the component 1 is heated or cooled before or during processing to facilitate the polymerising-process. For example, when wax is used as a mask material 6, the component may be dipped into a molten wax bath while blowing cooled air through the cooling configuration to cause the wax to thicken more quickly. In this case the entire component itself may be cooled before immersion into the wax bath in order to accelerate the thickening of the wax on the surface.

[0033] In an further embodiment an existing old coating is left on the component 1. In that case the cooling holes 4 are plugged and the old coating is removed by chemical etching after the plugs are in place. Then it is possible to coat the component 1 and remove the plugs as described above.

[0034] The most important improvement of the present invention over the prior art is that the cooling holes 4 are reformed during the coating deposition processes very close to their originally intended design, even through the thickness of the applied coating 9.

## 30 NUMBERING

### [0035]

- |    |  |
|----|--|
| 1  | Component, e.g. blades or vanes for gas turbines |
| 2  | Cavity   |
| 3  | Platform   |
| 4  | Cooling holes                                    |
| 5  | Flow   |
| 5a | Fluid containing abrasive particles              |
| 6  | Liquid mask material                             |
| 6a | Thickened mask material                          |
| 6b | Plug material for cooling holes 4                |
| 7  | External surface                                 |
| 7a | Internal surface                                 |
| 8  | Energy   |
| 9  | Coating  |
| 10 | Insert   |

## 50 CLAIMS

1. Process of plugging cooling holes (4) of a gas turbine component (1) with an external surface (7), comprising a cavity (2) and a plurality of cooling holes (4) before coating the gas turbine component (1), characterised in that

- mask material (6) is applied to the external surface (7) of the component (1) while a fluid is forced through the cooling holes (4).  
5
- the mask material (6) is thickened while the fluid is forced through the cooling holes (4).
- the cooling holes (4) are plugged with plug material (6b).
- the mask material (6a) is removed from the external surface (7) of the component (1),  
10
- the component (1) and the plugged cooling holes (4) are coated and
- the plug material (6b) is removed from the cooling holes (4).
  
- 2. Process of claim 1,  
characterised in that  
a fluid (5a) containing abrasive particles is forced through the cooling holes (4), after the thickening of  
the mask material (6) of the external surface (7) and  
before the cooling holes (4) are plugged.  
20
  
- 3. Process of claim 1 or 2  
characterised in that  
the mask material (6) extends to a length that is at least equal to the thickness of the coating (9) to be deposited beyond the external surface (7) of the component (1).  
25
  
- 4. Process of claim 3  
characterised in that  
the mask material (6) extends to a length of 200%-300% of the coating (9) to be deposited beyond the external surface (7) of the component (1).  
30
  
- 5. Process of any of the claims 1 to 4,  
characterised in that  
the thickening of the mask material (6) is done by means of an energy source.  
35
  
- 6. Process of any of the claims 1 to 5,  
characterised in that  
the mask (6) and/or plug material (6b) is an organic material.  
40
  
- 7. Process of the claim 6,  
characterised in that  
the mask (6) and/or plug material (6b) is a resin of a plastic, such as polyurethane, a polyurethane oligomer mixture, poly(isobutyl methacrylate), poly(vinyl toluene), polypropylene or a polypropylene / polyurethane oligomer mixture, the class of polymers vetones or silicones, or any photo-polymerizing resin or mix of resins.  
45
  
- 8. Process of any of the claims 1 to 5,  
characterised in that  
the mask material (6) and/or plug material (6a) is a powder.  
55
  
- 9. Process of claim 7 or 8,  
characterised in that  
the plug material (6a) contains particles of metal or oxide material such as silica, magnesia, calcia, alumina, zirconia, yttria or a mixture thereof.
  
- 10. Process of claim 8,  
characterised in that  
the plug material (6a) containing the metal or oxide particles is heated so as to volatilise or otherwise remove the organic portion of the plug material (6a) before the coating (9) are deposited on external surface (7) the component (1).  
15
  
- 11. Process of claim 9,  
characterised in that  
the plug material (6a) includes binding agents which are effective in holding together the solid particles of metal or oxide after the organic portion of the plug material (6a) is removed.  
20
  
- 12. Process of the claims 6,  
characterised in that  
the mask material (6) is a wax or a hydrocarbon.  
25
  
- 13. Process of any of the claims 1 to 5,  
characterised in that  
the plug material (6b) is a ceramic slurry or paste with essentially no polymerizing agent included.  
30
  
- 14. Process of any of the claims 1 to 13,  
characterised in that  
an insert (10) is placed in the cavity (2) of the component (1) before plugging the cooling holes (4).  
35
  
- 15. Process of the claim 14,  
characterised in that  
the component (1) is heated before or during any step of the process.  
40
  
- 16. Process of the claim 14,  
characterised in that  
the component (1) is cooled before or during any step of the process.  
45
  
- 17. Process of the claim 14,  
characterised in that  
the fluid which is forced through the cooling holes (4) is controlled in temperature.  
50
  
- 18. Process of the claim 1,  
characterised in that  
an old coating is left on during the masking process and plugging process and the old coating is removed from the component (1) by chemical etching after the mask material (6) is removed.  
55
  
- 19. Process of the claim 1,

characterised in that  
an old coating will be removed from the component  
(1) before applying the process.

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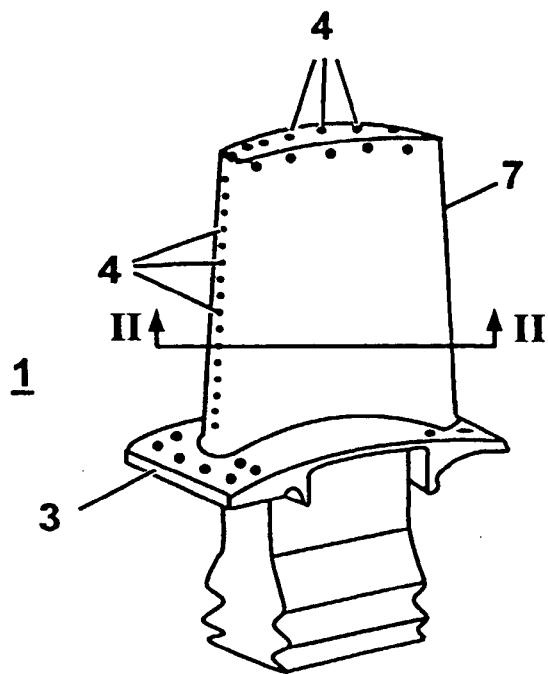


Fig. 1

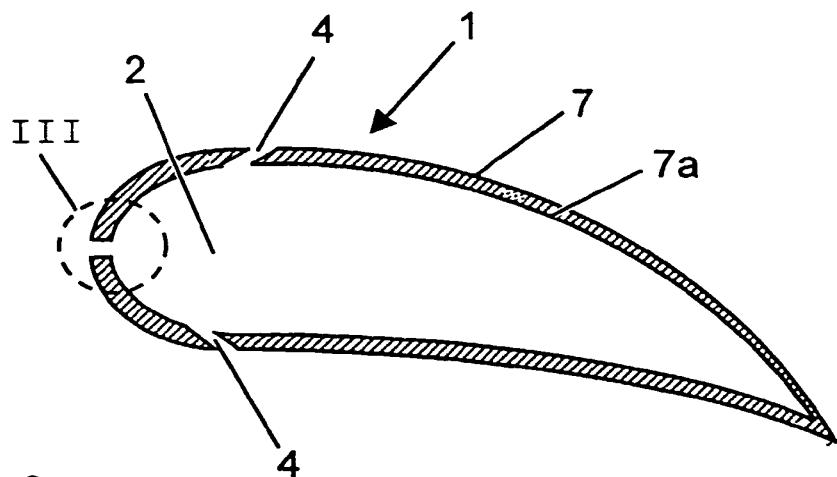


Fig. 2

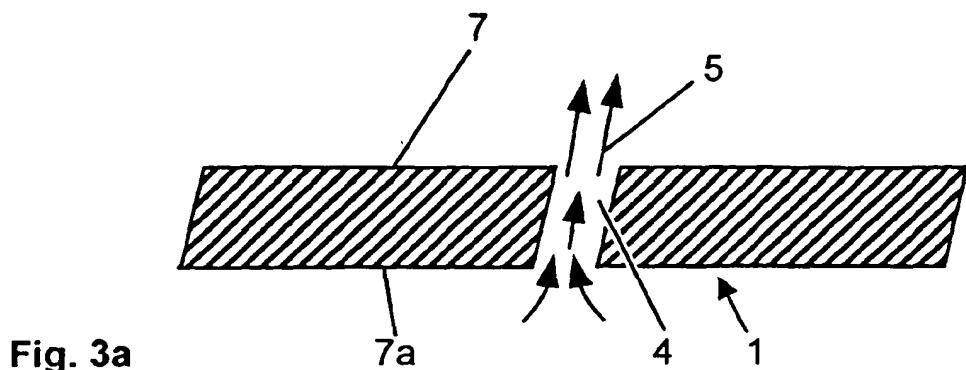


Fig. 3a

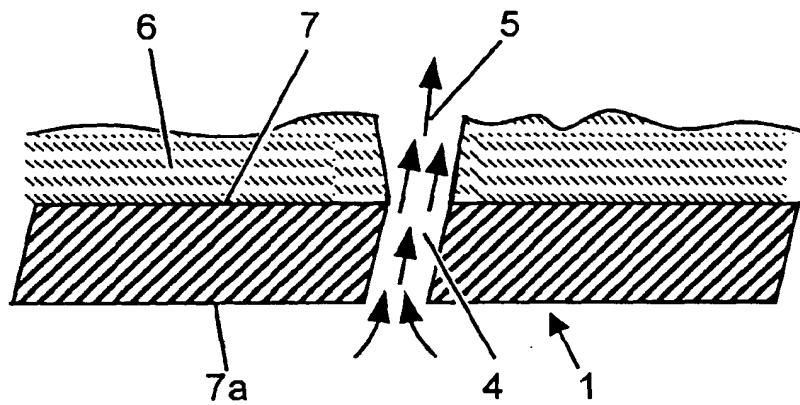


Fig. 3b

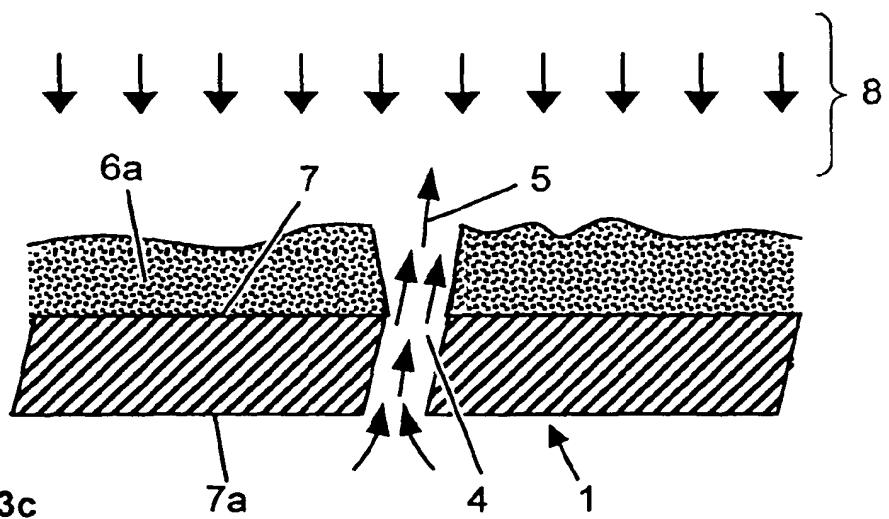
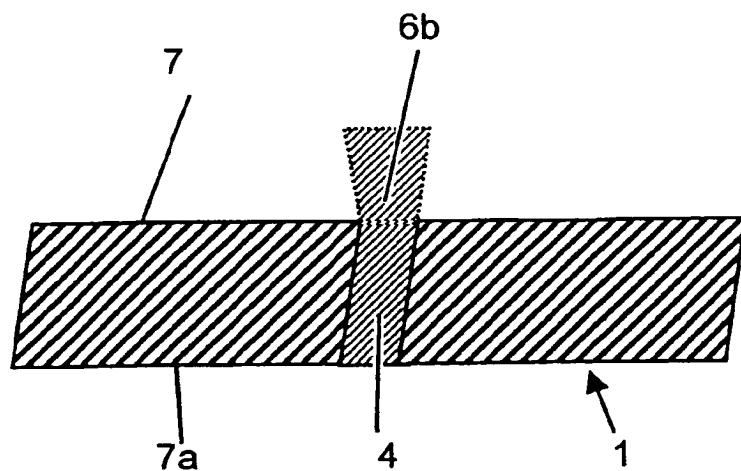
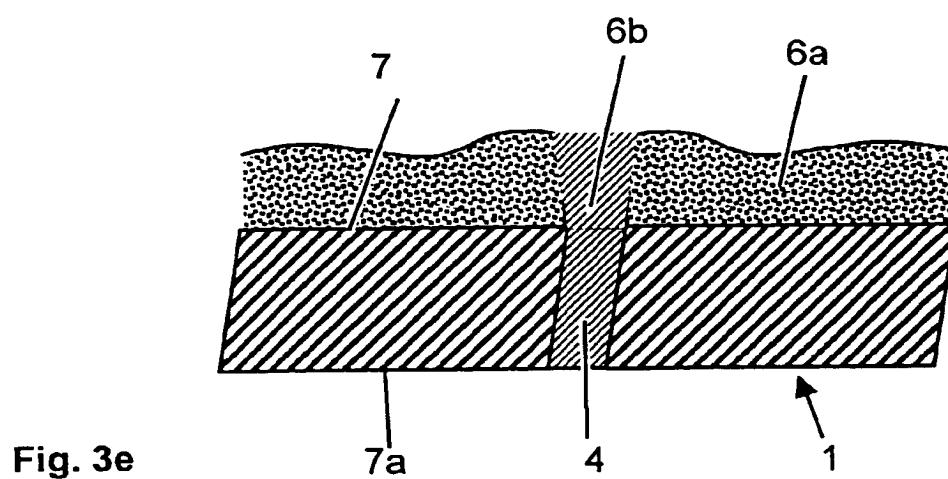
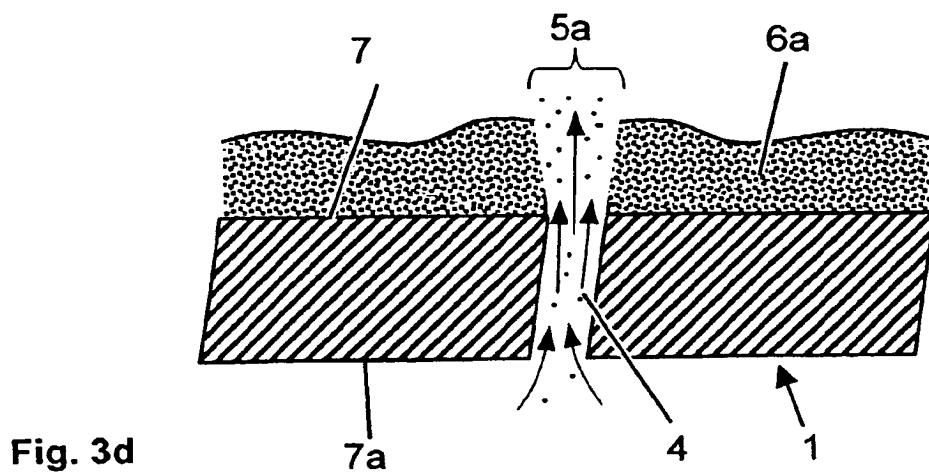


Fig. 3c



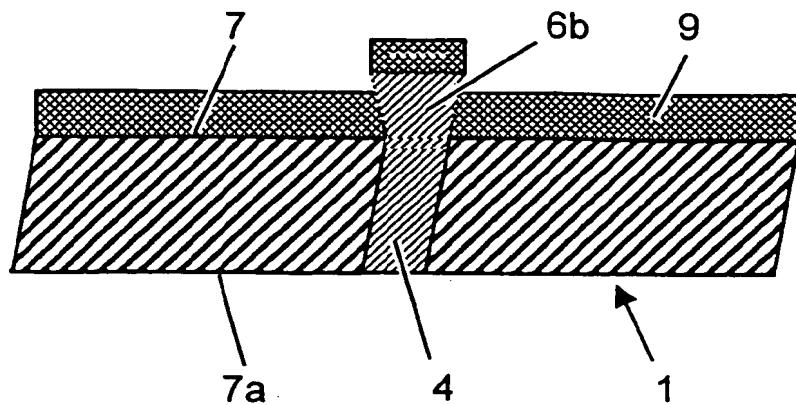


Fig. 3g

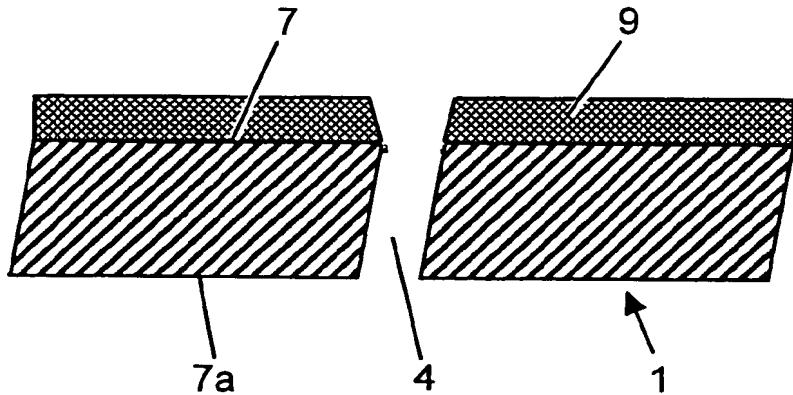


Fig. 3h

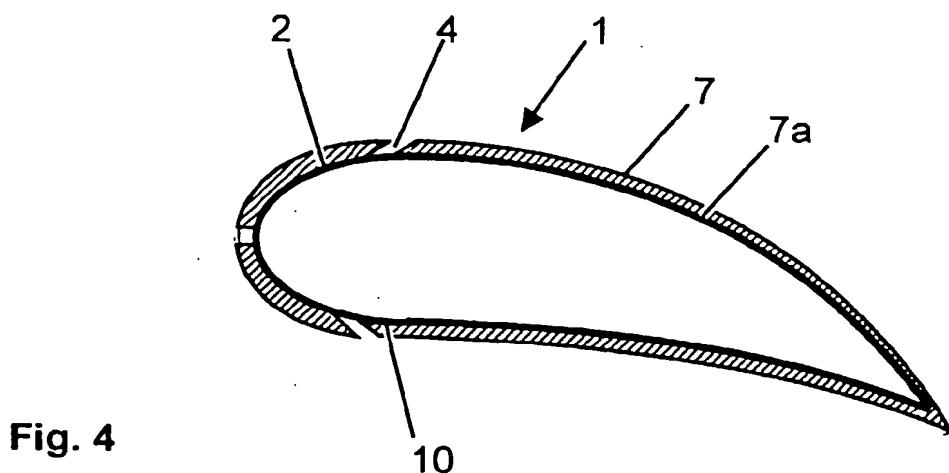


Fig. 4



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number

EP 99 81 0715

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 4 402 992 A (CURT H. LIEBERT) 6 September 1983 (1983-09-06) ---		C23C4/00 F01D5/28
A	WO 99 23273 A (SIEMENS) 14 May 1999 (1999-05-14) ---		
A	US 5 902 647 A (VENKAT SUBRAMANIAM VENKATARAMANI) 11 May 1999 (1999-05-11) ---		
A	EP 0 843 026 A (CHROMALLOY GAS TURBINE CORPORATION) 20 May 1998 (1998-05-20) ---		
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	18 January 2000	Elsen, D	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 99 81 0715

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
 The members are as contained in the European Patent Office EDP file on  
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18-01-2000

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